

Skin-to-Skin (STS) Operational Concept



**JLOTS
Force
Projection
from the Sea
R&D
Symposium**

**JAN 2004
Duck, NC**
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Skin-to-Skin (STS) Operational Concept



OVERALL OBJECTIVE:

To improve ship operations and the safe handling of cargo to increase throughput

- **Current process cannot even meet T-ACS designed throughput of 300 container/day offload (T-ACS Mission Operations Handbook) in SS-3.**
 - **Need system of systems approach (i.e. SRMS, PCS, IRBTS, INLS, Vacuum Mooring, Deep Draft Fender, etc.) to solve Seabasing in SS-4.**
 - **Must be able to reduce the effect of swell on ships and wind-drive surge to increase throughput**
- beca



Skin-to-Skin (STS) Operational Concept



Enabling Technologies for High Sea State Skin-to-Skin Cargo Transfer:

- Heading Selection and Control (i.e. motion prediction tool, DP)
- Ship-to-Ship Vacuum Mooring & Fendering
- Ship Motion Mitigation (i.e. SRMS/Rolls-Royce flume control)
- Enhanced Designs for Dry, RO/RO & Wet Cargo Transfer (i.e. PCS/IRBTS, INLS Spanning Ramp, IFFCAS)

Heading Selection & Control

From: Vessel Motion Analysis



CSC Vessel Motion Analysis:

- Originally developed by CSC, Advanced Marine, to analyze motions of a T-ACS, Containership & LCU-2000 for various orientations of wind driven waves and swell.
- Calculations were performed for all 576 combinations of sea and swell headings, allowing the user to specify both overall height and modal period for each, and presented in a 3D Excel file.
- Can be used to predict both relative and absolute motions for each vessel.
- Provides a tool to determine best vessel orientation in any give sea conditions.
- Analysis concept adaptable to other vessel combinations.

PROS:

- Can greatly reduce the vessel motions by identifying “sweet spots” in heading for current sea conditions.
- Incorporating wave measurement results into programming can provide automated updates on best recommended heading.
- Will simplify preplanning based on projected weather.
- Provides a tool that makes up for crew’s lack of familiarity with vessel.

CONS:

- Must be developed for each vessel.
- Greater variations in vessel parameters (i.e. total deadweight and GM) must be provided for.
- Will require some training for operation
- Spectrally based wave measurement will be needed.
- Limited to one heading of swell only, therefore requiring “testing” of each spectral source and assessing RAO’s for vessel(s) considered

Heading Selection & Control

Sample Analysis of Vessel Motion



Relative motion of: TACS-LOU 2000

Direction: Vertical

Displacement, ft

Acceleration, ft/sec²

Wave Conditions

Significant Wave Height, ft 4.24

Sea State 4

Sea Significant
Height, ft

3



Sea Modal
Period, Sec

7



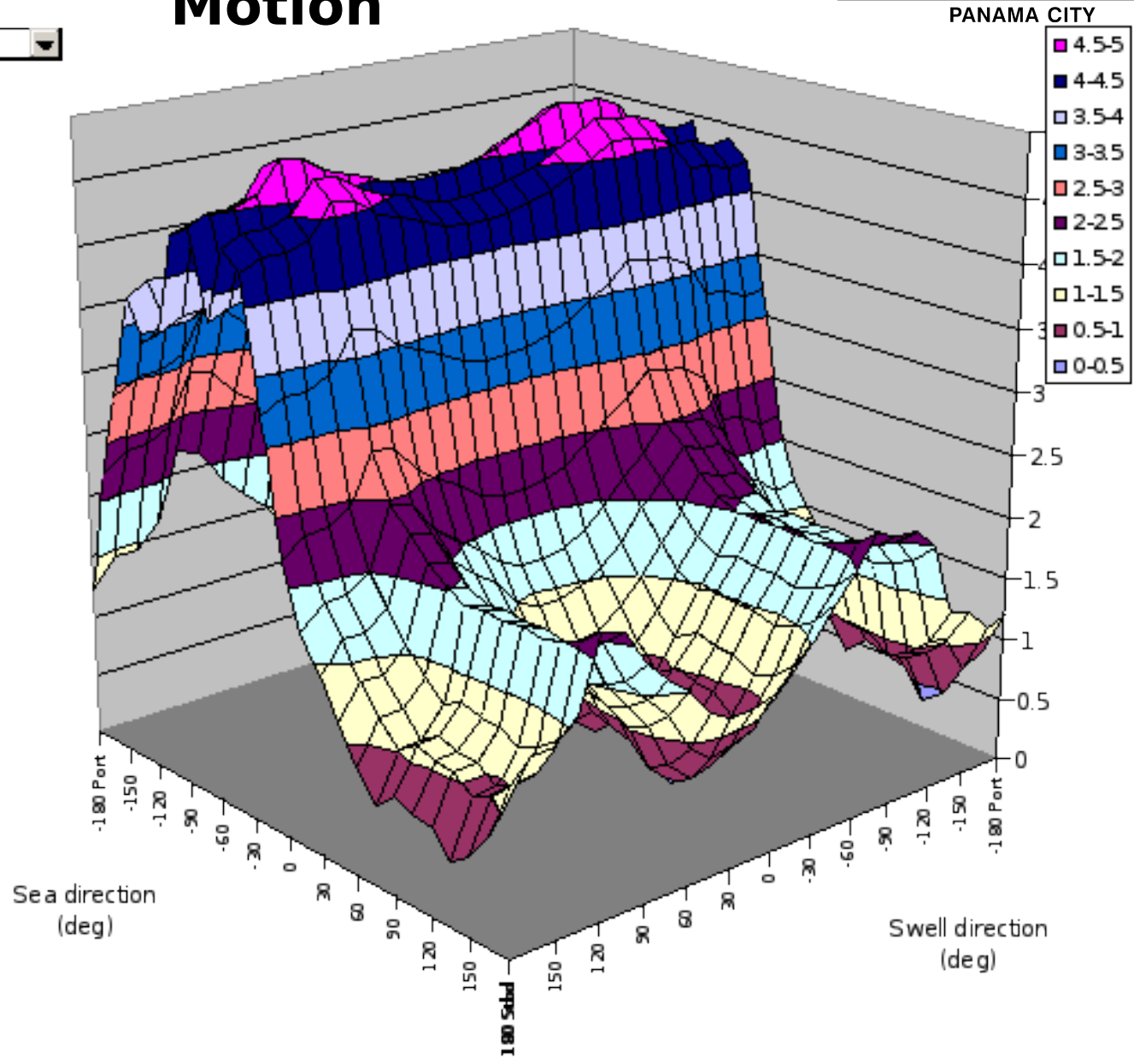
Swell Significant
Height, ft

3



Swell Modal
Period, Sec

16



Heading Selection & Control

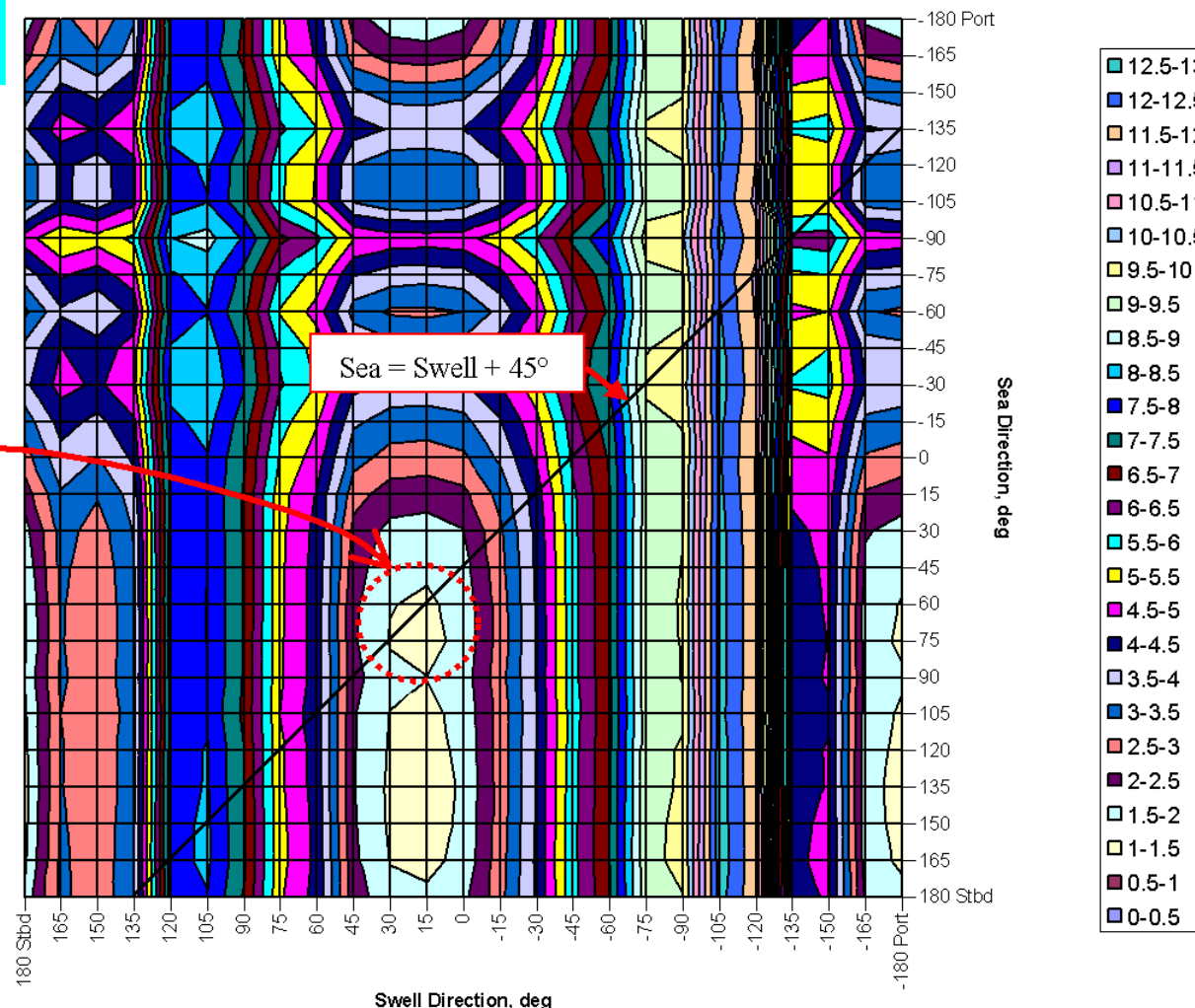
Example of Heading Selection



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Vessels: TACS-LCU2000
Direction: Vertical
dV/a: Velocity

Region of
Minimum Relative
Velocity



Contour plots of vessel motions can be used to find the best vessel orientation for any given sea conditions. In this example, the graph is rotated slightly clockwise and positioned for a top-down view. The plotted line represents the wind driven sea being 45 degrees clockwise from the swell heading. The minimum relative vertical velocity for the T-ACS and LCU is with the sea at 65 degrees and the swell at 20 degree off to the Starboard side relative to the T-ACS.

Heading Selection & Control

Dynamic Positioning (DP)



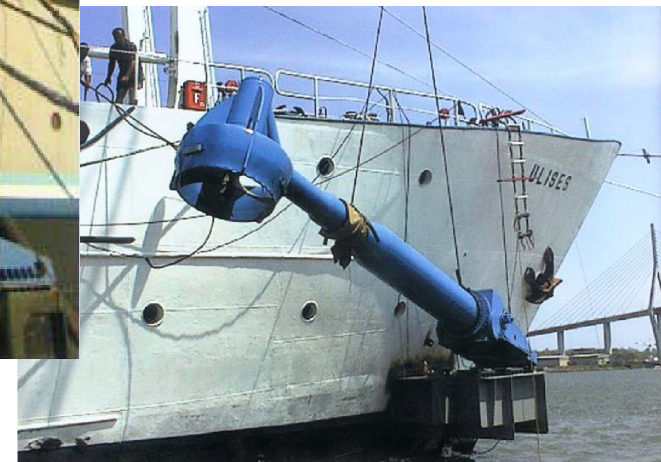
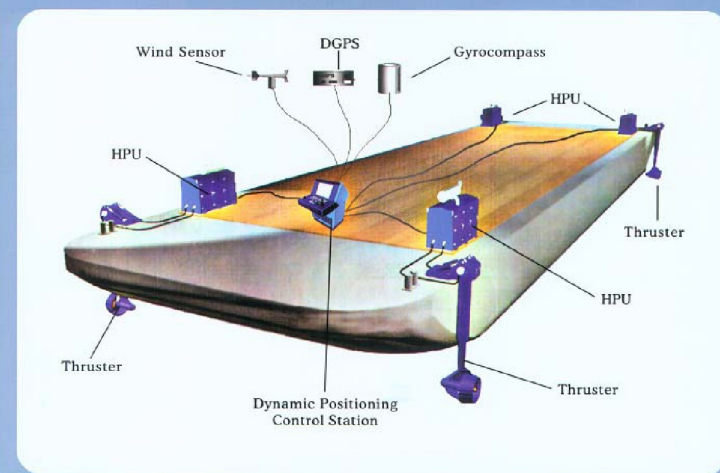
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DP Options for Testing:

- Thrustmaster provides a portable system complete with HPU and control packages for installation
- Allows testing on existing vessels without a major ship alt

Portable DP System works.

Typical System Configuration



Thrustmaster of Texas, Inc.
12227 FM 529
Houston, Texas 77041
Phone: 713-937-6295
Fax: 713-937-7962

Email: info@ThrustmasterTexas.com
Web: www.ThrustmasterTexas.com

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Ship-to-Ship Vacuum Mooring History



Originally By
Mooring International, Ltd.
Lyttelton, New Zealand



Original Vacuum Mooring System:

- Tutorial on first commercial application



Ship-to-Ship Vacuum Mooring Concept:

- Ship mounted vacuum system to attach to available freeboard of approaching

New Hardware by Mooring Systems, Ltd.:

- Redesigned application for pier based mooring (name changed from MIL to MSL).
- Mechanical/hydraulic link allows for changes in heel angle and ship draft.
- Improves system application by providing pierside attachment of **ANY** ship with adequate freeboard.
- Ship-to-Ship mooring would require more

Ship-to-Ship Vacuum Mooring

Concept Details

Vacuum Mooring Concept:

- Provides direct connection with adjacent ship using vacuum over a 1 to 2 square meter plate via hydraulic actuators.
- No manual labor required for mooring operation.
- Extremely fast operation moors \ll 1 minute, releases in 4 sec.
- Current system is being commercially produced for pierside mooring applications and can be scaled up for dynamic environment found with ship-to-ship mooring.

PROS:

- Extremely fast mooring (i.e. 10 - 30 seconds)
- Patented seal material is very secure and handles high shear loads as well
- Semi-rigid connection could reduce the relative motion between both vessels by 25% (see STS model results in Backup Section).
- Design of fender and mooring lines can be used for additional motion damping and control
- Potentially can allow vessels to remain

CONS:

- Adds weight and requires volume and power, though relatively small compared to the ship
- Adds to maintenance cost
- May still require fender and mooring lines for additional security during operations
- Would require development of integrated fendering and powered mooring lines for maximum improvement in motion damping and safety



Ship Roll Mitigation System (SRMS)



OBJECTIVE:

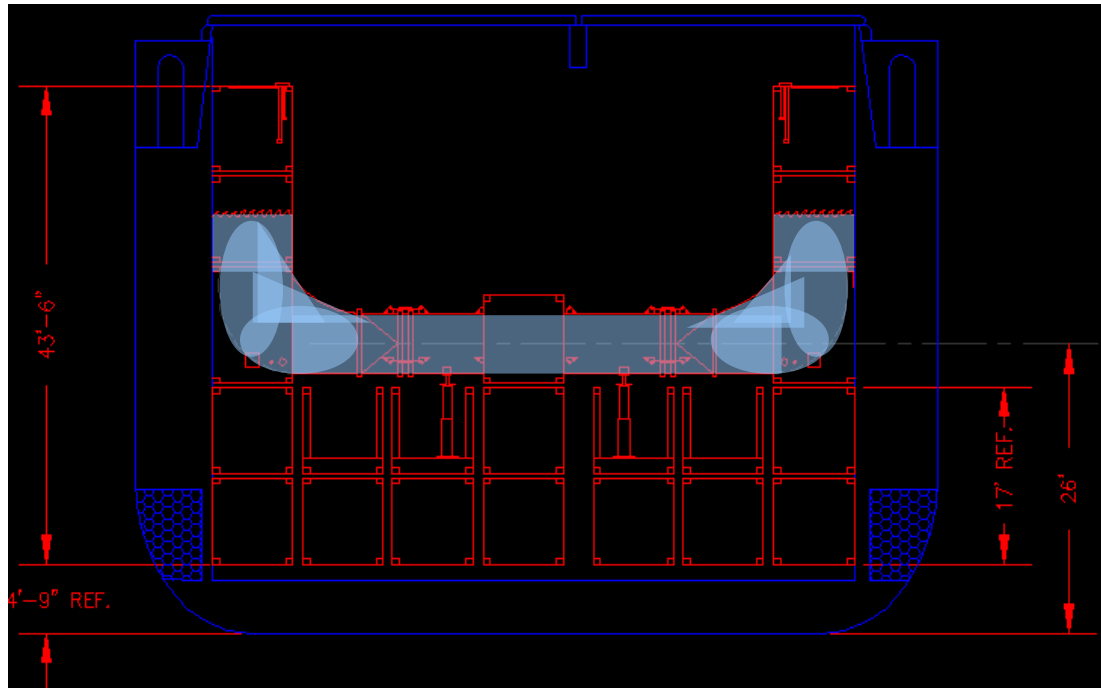
Investigate the Ship Roll Stimulator System (SRSS) concept to determine if controls can be adapted to mitigate ship roll through repeated system operation in opposition to wave caused ship motion

PAYOFF

Reduce ship motion from swells while at anchor during JLOTS cargo operations using the SRSS technology, which will continue to be used to create roll while pierside for testing and training.

STATUS/PLANS: DEC03

- Successfully tested in Skin-to-Skin demonstration OCT03.
- Report on test results for both SRSS 1/8th and full scale near completion.
- Recommendations for modifying flume control and testing will be investigated.



Ship Roll Mitigation System (SRMS)



SRMS Concept:

- Provides active dampening of ship roll by moving weight.
- Current system making use of existing hardware originally developed to stimulate roll for pier-side testing of cargo handling enhancements and crane operator training.



- Test results of will provide engineering data for costing and sizing active roll mitigation into new ship designs

PROS:

- ~~and prove feasibility of modular system for retrofit into existing hulls.~~
- Reduces wave induced roll motion of ship at least 40-50% and typically up to 60-80% (see Backup Files)
- Even in passive mode, system is still very effective over most conditions
- Active system improves roll reduction even further & removes possibility of inadvertently exciting increased roll at certain frequencies
- Reduced cargo motion improves safety to cargo crew, ship and lighter
- Reduces operator and crew fatigue due to working with less ship motion
- Increases operating range of cargo operations in high sea-state environment

CONS:

- Loss of cargo volume and weight
- Large cyclical demand on ship power if using active system operation
- Additional mechanical maintenance needed
- Additional complexity of debugging roll mitigation control by

Enhanced Crane Control



Enhanced Crane Control Concept:

- Involves powered and computer assisted control of crane +/- cargo to reduce pendulation of the load.
- Several systems have been developed or undergoing development:
 - Integrated Rider Block Tagline (IRBTS)
 - Platform Motion Compensation (PMC)
 - Pendulation Control System (PCS) - being developed by NSWC Carderock



PROS:

- Reduces cargo motion from own ship motion
- Improves safety to cargo crew, ship and lighter
- Reduces operator training time to gain proficiency in dynamic environment
- Increases operating range of crane in high sea-state environment

CONS:

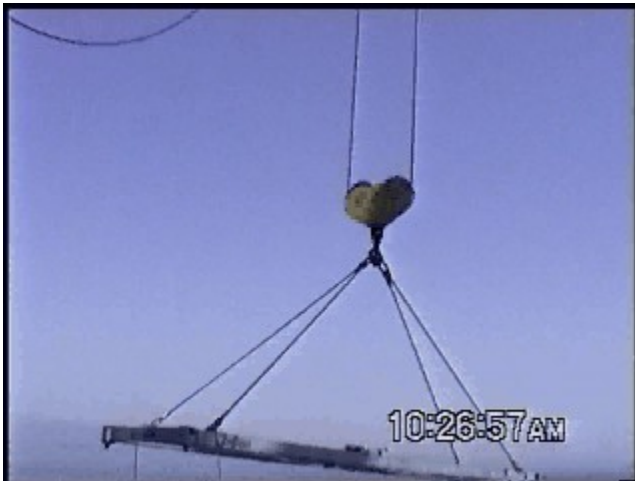
- Requires modification of existing cranes
- Increases power demand for handling loads
- Increases complexity of debugging crane control by ship crew

Enhanced Crane Control



Enhanced Crane Control:

- Load pendulation is sensitive to vessel motion induced by ocean swell and to wind gusts
- Crane control systems proven to mitigate pendulation
- Work recommended to optimize PCS system and integrate into current crane design with CC2000 control card aboard TACS 5



IRBTS



PCS

Skin-to-Skin (STS) Way Ahead



Proposed R&D for Skin-to-Skin:

- Heading Selection Tool
 - FY04 - Compare current tool with CSC STS modeling results
 - Recommend improving tool for practical heading selection
- Ship-to-Ship Vacuum Mooring
 - FY04 - Conduct a calm water STS operational test w/ARATERE in NZ
 - FY04 - Investigate operational benefit of vacuum mooring via CSC modeling
- Ship Roll Mitigation System (SRMS)
 - 4th Quarter Demo results indicates benefit of passive roll mitigation
 - Recommend investigation of optimal roll mitigation system for MPF(F)
- Enhanced Cargo Transfer
 - Recommend merging PCS/IRBTS for crane control
 - Recommend investigation of methods for RO/RO and liquid transfer for Seabase

Skin-to-Skin (STS) Operational Concept



BACKUP SLIDES

- **STS Modeling Results**
 - **SRMS Data**

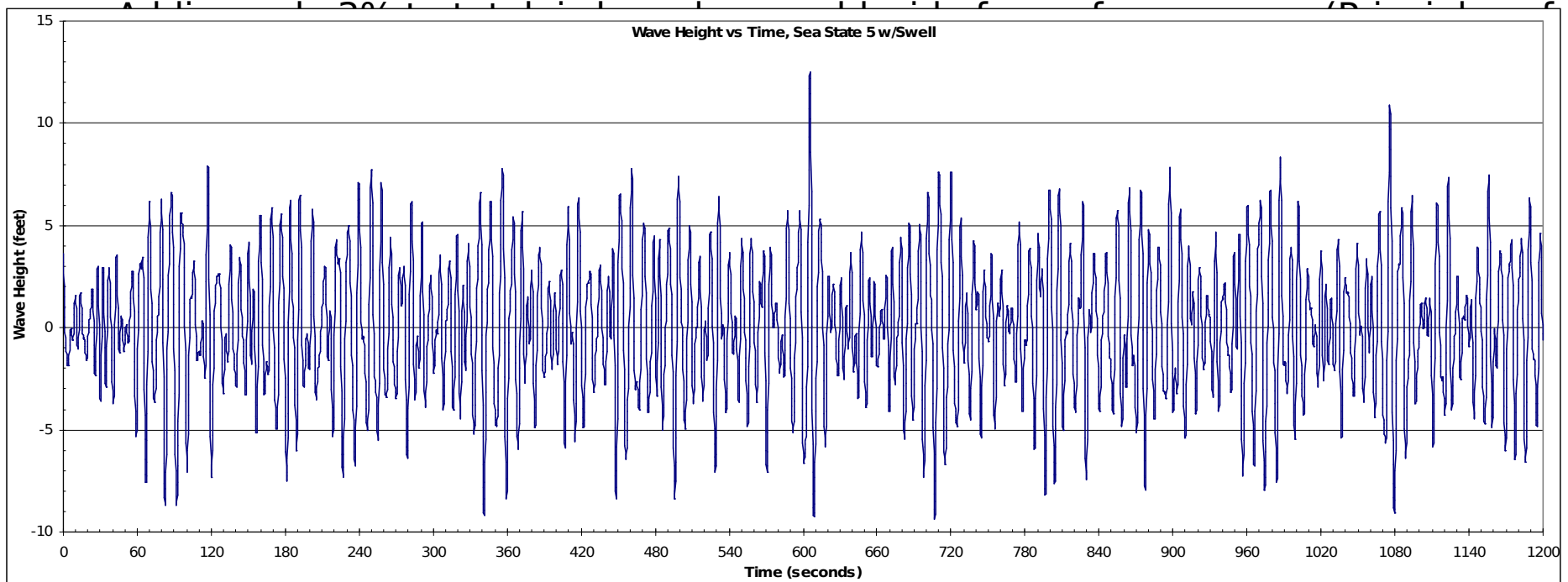
Ship-to-Ship Vacuum Mooring



Modeling: Waveform

Waveform Description:

- Wave height and period determined from two sets of data.
- First set of frequency groups developed from wave variance vs frequency graph for 24 knot wind
 - Principles of Naval Architecture 2nd Rev., Vol III, page 14, Figure 9 (Moskowitz, et al, 1962).
 - Pierson-Moskowitz type waveform for **wind driven** sea state 5 with 11 ft. significant wave ht.
- Second set of frequency groups includes longer swell component



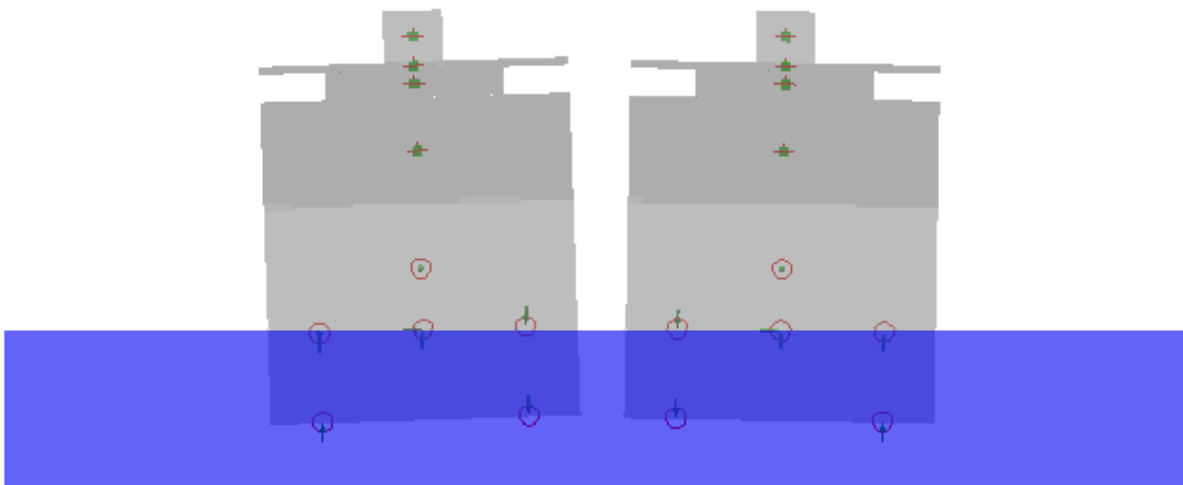
Ship-to-Ship Vacuum Mooring



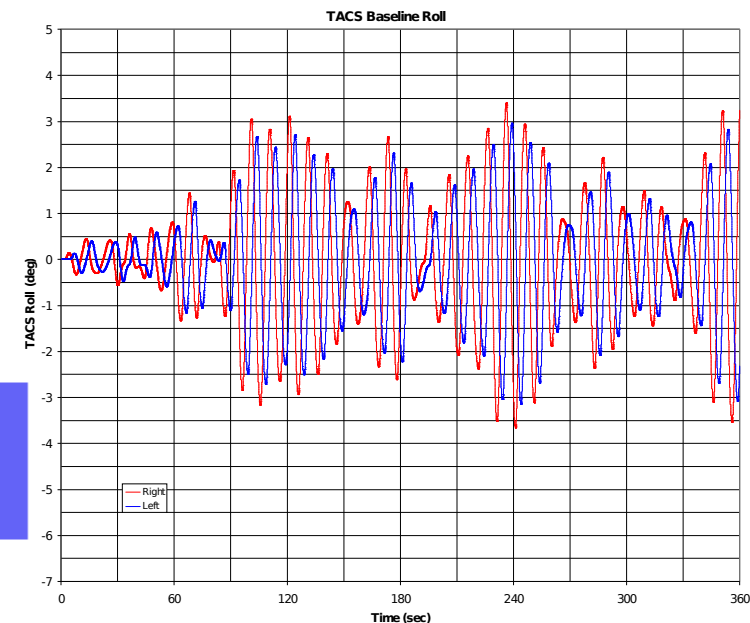
Modeling: T-ACS Vessels

T-ACS Modeling:

- Modeling done in MSC visualNastran Motion in athwartship direction.
- Each vessel is an independent mass “buoyed” up by forces designed to emulate water displacement and righting forces on hull.
- Hull righting moment, roll period and roll decrement are adjusted to match known ship data.
- Wave induce forces are pre-calculated in Excel and imported into Motion to save on run time.
- Second vessel roll reaction is phased downstream of first vessel with reduced wave energy (90%) to allow for reflective and turbulent losses.



Unzip movie file: T-ACS Base Line without mooring
26SEP



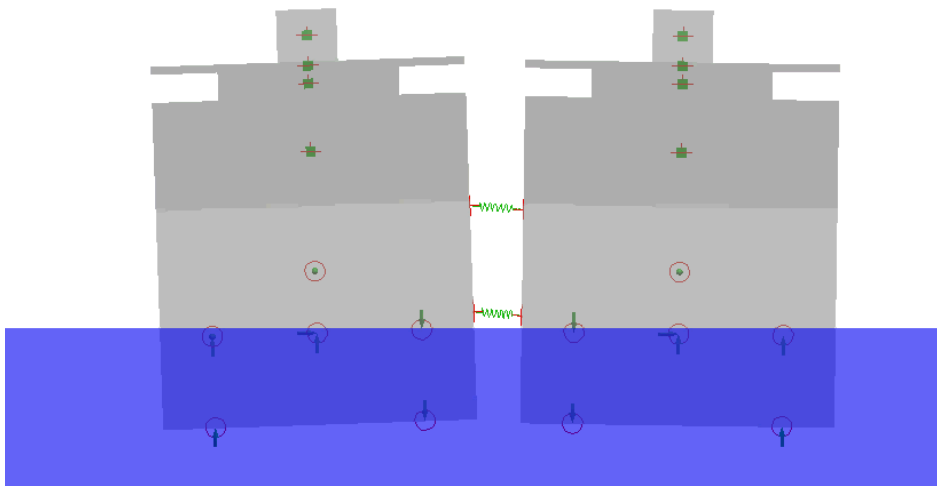
Ship-to-Ship Vacuum Mooring



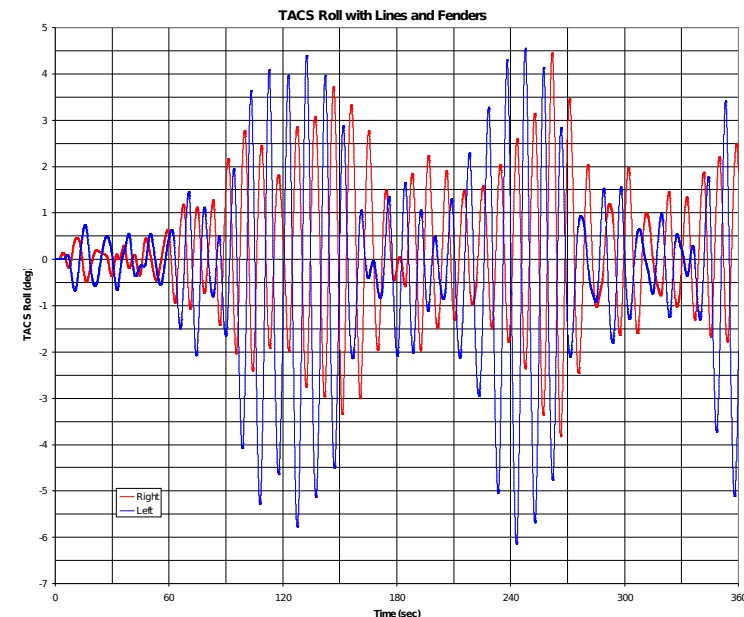
Modeling: Traditional Mooring

Mooring Modeling:

- Fender data obtained from Seward website
 - Forces based on 11 foot diameter standard fender
 - Fender modeled as a damped spring
- Mooring lines are based on NAVSEA 4th Quarter Skin-to-Skin Demo plan in OCT2003
 - Modeling of mooring lines forces are only acting in athwartship direction
 - Forward and aft lines were consolidated into two distinct forces
 - Created by combining force vectors of each line for athwartship direction
 - Forces were represented by a lightly damped spring



Unzip movie file: Mooring with Lines and Fender
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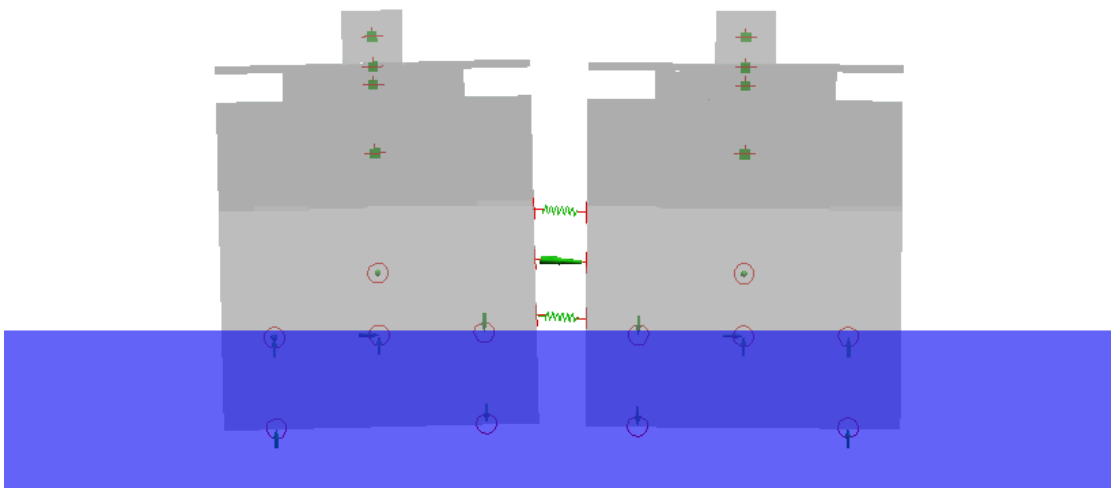
Ship-to-Ship Vacuum Mooring



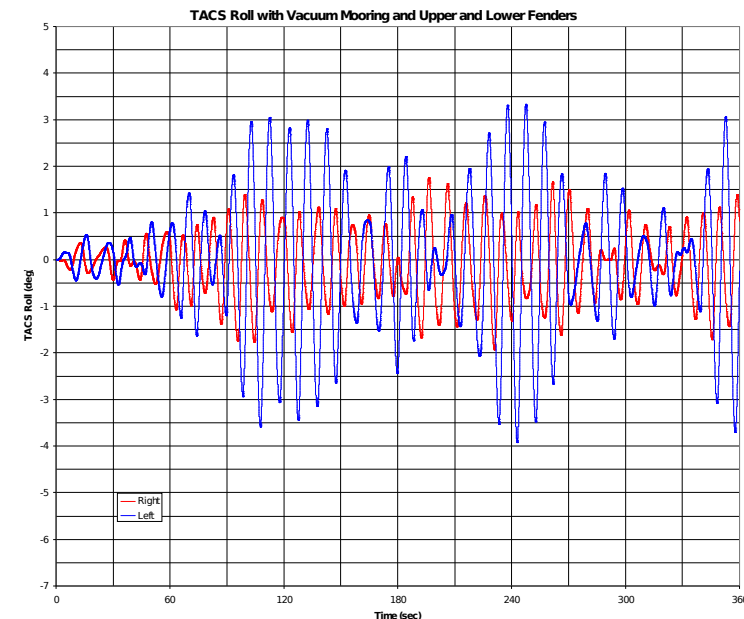
Modeling: Vacuum Mooring

Vacuum Mooring Concept:

- Only two connections (FWD & AFT) used
 - Third connection assumed to be in “adjustment” mode and not included for this analysis
- Ship separation maintained by hydraulic connection used for vacuum mooring
- Fenders provide buffer from extreme motion
- Hydraulic forces limited to maximum of 80 tonnes for each set
- Ships maintained reasonable distances of between 9 to 15 feet



Unzip movie file: Mooring 80 Klb Vac & 2 Fenders
26SEP



Ship-to-Ship Vacuum Mooring



Modeling: Concl. & Recommendation

Conclusions:

- Simulation of even Sea State 5 was not as challenging as anticipated due to limited swell component over that of a purely wind driven storm.
- Vacuum Mooring reaction forces and motions are reasonable for T-ACS sized vessels.
- Relative motions were reduced by 15 - 40% with Vacuum Mooring.
- Optimizing control algorithms for hydraulic connections could further reduce relative motion.
- Current system is being commercially produced for pierside mooring applications and can be scaled up for dynamic environment found with ship-to-ship mooring.

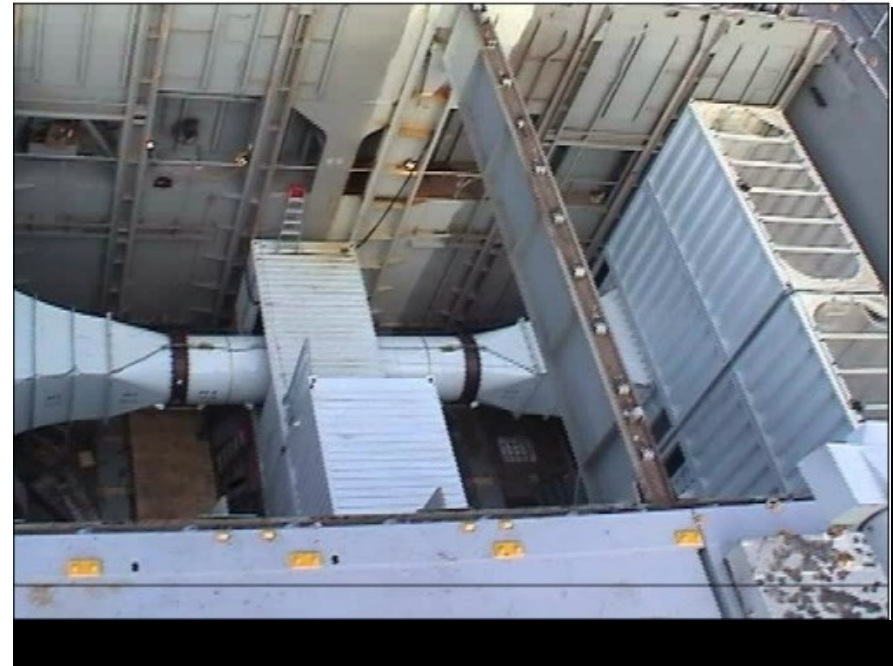
Recommendations:

- Improve modeling for force and motion analysis
 - Include full 3-D model for 6 DOF motion
 - Verify motion w/r larger swell components using 50, 70 and 90 percent probability data for worldwide occurrence
- Model mass-spring-damper system for feedback control parameters
- Conduct initial design analysis and identify high risk issues

Ship Roll Mitigation System (SRMS)



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MID-RIVER TEST: 25SEP02

- Demonstrates ability of hardware to stimulate and possibly mitigate ship roll.
- Obtained +/- 3.5 degree roll in York River with an 11.8 sec. stimulation period in approx. 35 foot water depth (not ideal).
- Test used to help select new props.
- Ship stability was verified for

SRSS Removal: 18DEC02

- SRSS removal required for shipyard repair and possible activation.
- Operational requirement to have system removed within 48 hours.
- Total time for all operations was under 24 hours.
- The FLICKERTAIL STATE (T-ACS 5) will be in JLOTS exercise off of Honduras in FEB-MAR '04.

Ship Roll Mitigation System (SRMS)



NAVSEA 4th Quarter Demo: Purpose

- Provided showcase of current NAVSEA developments for Seabasing using FLICKERTAIL STATE (TACS 5) and sister ship, CORNHUSKER STATE (TACS 6).
- Used to identify shortfalls in concepts and mooring procedures.
- Demonstrated nominal procedures for Skin-to-Skin mooring.
- Provided data on full scale SRMS system for comparison with 1/8th scale SRMS model.
- Proved the benefit of SRMS in ship roll reduction with respect to differences in motions between identical vessels.



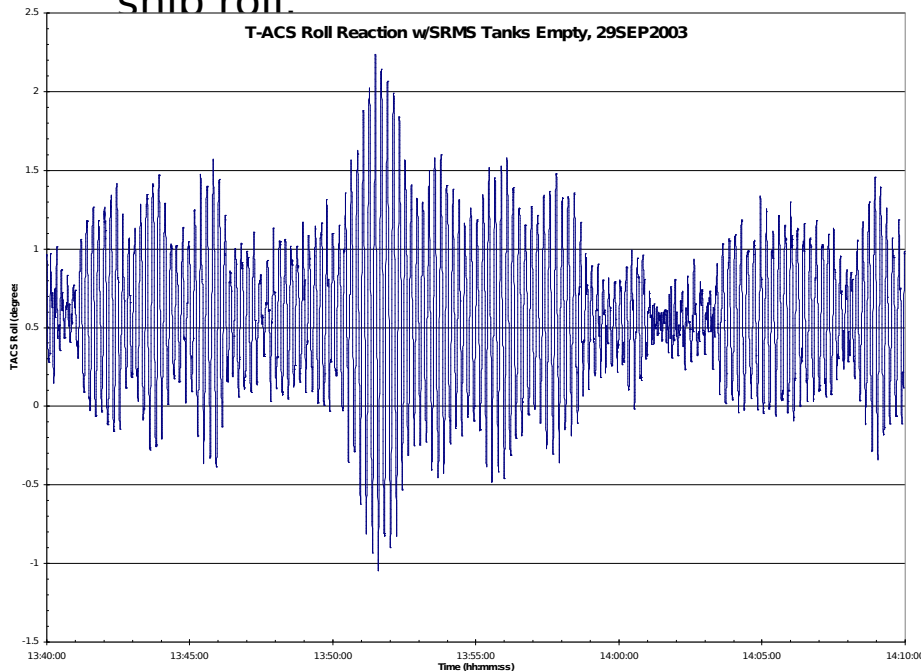
Ship Roll Mitigation System (SRMS)



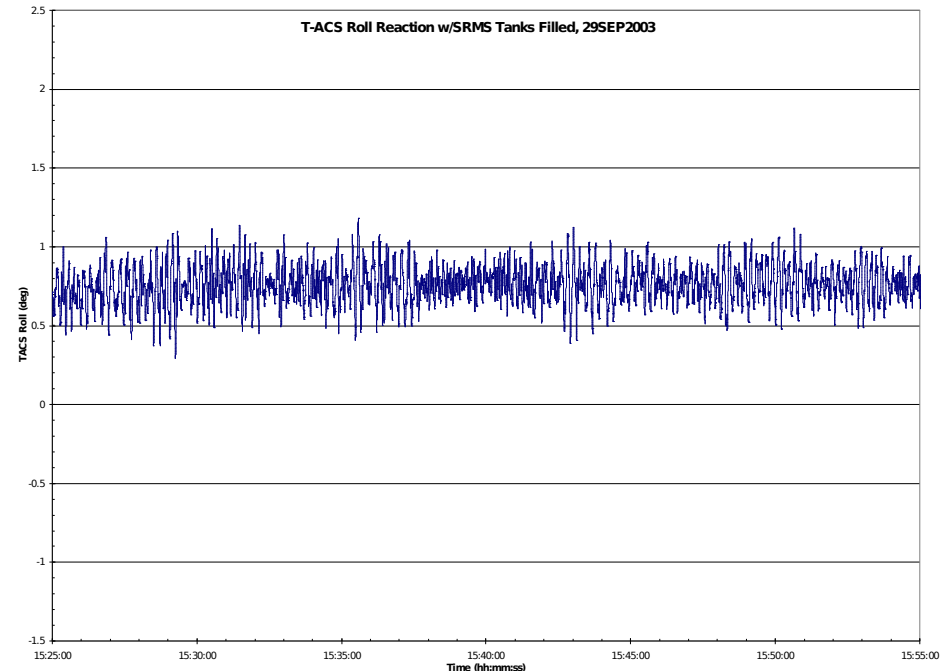
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NAVSEA 4th Quarter Demo: Passive Results of Full Scale SRMS

- Benefit of SRMS passive roll mitigation demonstrated during fill process (1.5 hours).
- Overall roll reduction was on the order of 50-75%.
- SRMS effectiveness relative to flume tank natural frequency.
 - Flume natural frequency for tank water motion was very near vessel roll natural frequency.
 - Flume water phase was therefore near theoretical ideal of 90 degree lag behind ship roll.



Roll Reaction Before Flume Tanks Were Filled



Roll Reaction After Flume Tanks Are Filled

Ship Roll Mitigation System (SRMS)



Conclusion:

- Demonstrates ability of hardware to mitigate roll
 - Passive mitigation on full scale shows roll reduction of 50 - 75% for small rolls of +/- 2 deg
 - Active mitigation on 1/8th scale shows roll reduction of 65 - 80% for large rolls of +/- 6 deg
- Visual reports of ship roll for FLICKERTAIL STATE (TACS 5) was much less than identical sister ship, CORNHUSKER STATE (TACS 6)
- Crane lifts aboard TACS 5 were reported easier whenever SRMS was actively operating
- New propellers used in test showed greater control over moving the water in the flume.
- Results for active SRMS control not fully analyzed yet and should lead to new control concept
- Results of 1/8th scale and full scale SRMS tests will provide engineering data for designing active flume systems into new build vessels
- SRSS/SRMS hardware serves as a proof of concept of a modular flume system for possible retrofit into existing vessels

Recommendations:

- Continue to develop control algorithm using 1/8th scale
- Continue to test full scale system with every exercise of opportunity (i.e. Honduras)
- Investigate alternative control methods (i.e. Rolls-Royce, Flume)